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Tracking non-native vertebrate species: indicator design for the United States of America

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Abstract. Basic information on the distribution, spread and impacts of non-native species in the USA is not available to those who shape national environmental policy. Although the USA spends billions of dollars annually on introduced species research, monitoring and control efforts, only a limited number of government agencies or private institutions are able to provide definitive reports on more than a handful of these species at a national scale. Research on invasive species is only of marginal practical value if the information cannot be succinctly and effectively transmitted to those who determine the management policies, budgets and objectives. To remedy this situation, a national-scale approach for monitoring established non-native species has been developed under the auspices of the Heinz Center as part of 'The State of the Nation's Ecosystems' project. This paper specifically describes the strategies for reporting on indicators for non-native vertebrate species developed through inputs by experts from academia, industry, environmental organisations and government.

Introduction

The introduction and spread of invasive non-native species is among the top environmental issues in the USA. Understanding the spatial and temporal dimensions of this problem requires consistent and reliable information. Managing the problem requires this information to be delivered to decision makers and the public in concise form. To accomplish this, sound sampling designs are needed for the collection of data that are comparable across a variety of species, scales and ecosystem types, and these data need to be consistently available to decision makers in the form of a small number of credible, accessible indicators. Funding and human resources typically are scarce, making coordination and cooperation necessary among federal, state, and local agencies as well as collaboration with private institutions and industry. Although we focus on indicator development for the USA, the issue of indicator design for describing and disseminating information on the general status of non-native species is not exclusive to the USA. Other nations share similar concerns for non-native species, for example Australia (see Gibson and West 2006) and the UK (see http://statistics.defra.gov.uk/esg/indicators/ and http://www.jncc.gov.uk/page-3966/).

United States ecosystems serve as habitat for more than 200 000 native species (Adams *et al*. 2000). Biological invasions pose one of the greatest threats yet identified to species and ecosystems (Mooney and Hobbs 2000; NISC 2001). They are among the top drivers of environmental change (Sala *et al*. 2000) and have had an impact on at least half of the species listed as threatened or endangered in the USA (Wilcove et al. 1998, but see Gurevitch and Padilla 2004; Ricciardi 2004; Clavero and Garcia-Berthou 2005). Established non-native species can alter the structure and function of ecosystems at all levels of organisation (i.e. from altering genetic compositions to altering landscapes) and invasive non-native species have significantly increased operating costs for industry, agriculture and infrastructure (Pimentel *et al*. 2000, 2004). Non-native species are able to colonise a diverse array of habitats, from the oceans and coasts to the mountains and from deserts to the subtropics. Costs associated with invasive non-native species have recently been estimated to exceed US$100 billion annually, US$41 billion of which is attributed to human and agricultural diseases (Daszak *et al*. 2000; Pimentel *et al*. 2000, 2004).

Non-native species and the 'State of the Nation's Ecosystems' report

Developed under the auspices of the H. John Heinz III Center for Science, Economics and the Environment, with funding from the US federal government, foundations and corporations, 'The State of the Nation's Ecosystems' is a comprehensive report on the condition of the USA's lands, waters and living resources (Heinz 2002). The report provides essential information to aid local, state and national environmental policy makers, as well as the general public. First published in 2002, 'The State of the Nation's Ecosystems' is an ongoing and expanding scientific effort updated every 5 years. Here, we describe and critically assess the indicators for tracking non-native vertebrates in the USA developed for inclusion in the 2007 report.

Non-native species defined

Species are regularly introduced to new habitats. Most introductions result from human activity, either inadvertently or purposefully. Introduced species capable of growing in the wild, without cultivation or any kind of human intervention, are termed here as 'non-native' species. Once a non-native species

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has begun to successfully reproduce in a given location, we term it as an 'established non-native' species. Not all introduced species become established. Those that establish and spread might also permanently change their new environment. To distinguish established non-native species recognised as harmful from those for which negative impacts have not been identified, we label as 'invasive non-native' species the established non-native species that additionally: exert a detrimental impact on the environment, cause economic loss or present human health risks. Introduced species that only survive with persistent human intervention typically have horticultural, agricultural or other value, and we do not include them among non-native species indicators.

Objectives and framework for indicator development

Development of a system for national-scale (or any other scale) monitoring and reporting of established non-native species is critically needed. Many papers and reports have outlined research needs to address invasive and non-native species in the USA (e.g. Ewel *et al*. 1999; D'Antonio *et al*. 2001; Chornesky *et al*. 2005). Basic information on the current distribution, spread and impacts of non-native species already established in the USA is lacking. A successful system would make the necessary data available, provide a means to distill the data into a useful and understandable form (indicators) for application by decision makers, and thereby provide the nation with tools for understanding the connections of non-native species with ecological resources, human health and the economy, and for evaluating the success of mitigation efforts. Research on invasive species is only of marginal practical value if the information collected cannot be succinctly and effectively transmitted to those who determine the management policies, budgets and objectives.

The limited amount of data available on colonisation by non-native species at large scales is rooted in a lack of basic monitoring programs. However, the data gap is also partly a result of the absence of standardised methodologies for collecting these data, which confounds aggregation of information across those ecosystems or regions with monitoring programs already in place. Our intention has been not only to encourage new monitoring programs, but also to encourage existing monitoring programs to seek opportunities for coordinating methodologies.

The strategies for reporting on non-native species were developed around four major taxonomic groups: plants, vertebrates, invertebrates and plant and animal pathogens. Although these four groups do not provide exhaustive coverage of species in the USA (e.g. most microorganisms are not included), they represent a large portion of non-native species and include the most widely studied taxa. In this paper, we specifically focus on indicators applicable to non-native vertebrates.

Indicators of non-native species have to meet particular criteria. First, they have to be scientifically credible to merit application. Second, they need to provide useful information to policy makers and the public on the establishment and spread of non-native species. Third, they have to have feasible resource requirements for data collection.

Non-native versus invasive species indicators

In order to capture broad changes in USA ecosystems that would be missed by focusing on only invasive non-native species, and because the science is not sufficiently advanced to completely determine whether a given non-native species has potential to become invasive, a strategy of reporting on all established non-native species was followed. On one hand, a non-native species may not show harmful traits for years or even decades after becoming established; such delayed impacts could, for example, occur after local conditions change or as a species spreads to more susceptible locations. On the other hand, negative impacts may occur but go unnoticed; for example, effects on nutrient cycling rates, which are not easily observed. One might consider this a corollary to the rule of 10s (Williamson and Fitter 1996): where a subset of exotic species persists, a subset of those becomes established, a subset of those causes harm and a subset of those is recognised as causing harm. It is also useful to track all established non-native species because they are the source pool from which invasive non-native species emerge. Tracking the larger set of species provides information on the relative risk of non-natives becoming invasive and can reveal patterns that point to or correlate with previously unidentified negative impacts.

An additional challenge for reporting only invasive non-native species is that the very same species could be simultaneously harmful and beneficial, or both, depending on the ecosystem in which the species becomes established or on one's point of view. Similarly, in some cases, trade-offs exist between the benefit of an introduced species as seen by one sector of society and a cost seen by another. For example, anglers often value the wide distribution of rainbow trout (*Oncorhynchus mykiss*) because they provide substantial recreational value. However, the same species may be of concern where managers are attempting to restore native cutthroat trout (*Oncorhynchus clarki*), because rainbow trout can cause significant harm through interbreeding and competition (Behnke *et al*. 2002).

The list of species that have been introduced to the USA includes some that provide clear benefits and others that may never cause any problems. The definition of non-native species we apply, however, reduces this bias. Populations of introduced species requiring cultivation or care by humans are not included in these indicators. By excluding these, the indicators avoid reporting on many agricultural, ornamental or other species purposefully introduced for the benefits they provide. However, some cultivated species can spread beyond the sites of introduction. Established feral populations of such species, but not cultivated populations, are included in the indicators because they may exert harmful impacts once established outside the ecosystems or areas where they provide benefits. For example, domestic house cats are beloved pets of some people, but those that are allowed outdoors and wild populations of feral cats kill millions of birds and small mammals each year (e.g. Lepczyk *et al*. 2004).

Indicator design

The non-native species indicators have been designed to be applicable across the six major ecosystem types in the USA as identified by 'The State of the Nation's Ecosystems' report (Heinz 2002): coasts and oceans, farmlands, forests, freshwaters, grasslands and shrublands and urban and suburban areas. Ecosystem-based coverage was adopted for the non-native species indicators both for consistency with 'The State of

the Nation's Ecosystems' report and because of the comprehensive coverage it provides (Heinz 2002).

A species' status as native or non-native is to a large degree a spatial problem. A species is considered non-native when it becomes established beyond its native range, but potential for confusion arises when the species' status is described with respect to other boundaries (e.g. political boundaries such as counties, natural boundaries such as watersheds etc.). For example, the redeye bass (*Micropterus coosae*) is native to certain drainages within a number of south-eastern states, so it is considered native to the USA. However, redeye bass are also established in California (Fuller 2006), so the species can also be considered a non-native species established in the USA. An additional spatial consideration is that a wide-ranging species may have to be transported across the continent before leaving its native range, whereas some localised, stationary species could be considered non-native to an immediately adjacent county. There are also species whose ranges have expanded or contracted without human influence, changing what can be considered their native range. Ultimately, the determination of a species status as native or not must be made for a specific location and with respect to a spatial scale appropriate to that species.

It is possible to use a variety of 'lenses', such as county or watershed boundaries, to roll up these data across species into aggregate indicators. If a species has both native and non-native populations within the area considered, such as the redeye bass with respect to the entire USA, then it is included in the tally of non-native species. Thus, the scale of geographic application would influence whether some species are included as non-native for indicator calculations. Where possible, watersheds defined by their US Geological Survey 6-digit Hydrologic Unit Code (6-HUCs) may be used to aggregate data on non-native species, because 6-HUCs are relatively similar in size across the country and are large enough in number (there are 334 6-HUCs in the lower 48 states) to reasonably present distributions in the indicators. Watersheds also form units more consistent with ecological reality for native species and the establishment of non-native species than politically determined artificial boundaries such as county or state lines.

The two indicators identified as most feasible and effective for conveying the status of non-native vertebrates (as well as other taxa) within the above design parameters were: (1) percentage of species that are established non-natives; and (2) number of new non-native species established over time.

Percentage of vertebrate species that are established non-natives

As an indicator, the percentage of all species that are established non-natives can aggregate site-specific monitoring data on non-native and native species for vertebrates (as well as the other three major taxonomic groups – plants, invertebrates and pathogens) into a national-level assessment of colonisation by non-native vertebrate species. Additionally, this indicator can provide a core national indicator for all non-native species' colonisation that integrates comprehensive information on all established non-native species from all taxonomic groups and across all ecosystem types.

The percentage of species that are established non-natives can be flexible in terms of the scales, ecosystems and taxonomic groups of interest. It could be used to report by ecosystem type or by taxonomic group. For instance, an indicator of this type could be used to aggregate data across all ecosystems and taxonomic groups within a single state, or it could be used to report on a single taxonomic group throughout all of the nation's forest ecosystems.

The proportion of species that are established non-native species is a broad measure of the intensity of colonisation by non-native species in various habitats. This measure relates to the intactness of a biological community, because areas with greater numbers of established non-natives relative to the total species richness have a community of species different from a community of native species. Monitoring efforts may report the number of non-native species detected in an area, but reporting the percentage of all species that are non-native provides context for this number. For example, knowing that a watershed is colonised by five non-native species is useful, but knowing that those five species constitute half of the species in the watershed provides significantly more information about the ecosystem and conveys a greater indication for potential ecological change.

Large-scale indicators reporting the percentage of species that are non-native (either within vertebrates or across all taxa) provide an overarching picture and can guide policies intended to reduce impacts by invasive species. A positive trend would be a reduction in indicator value, which could result from successful application of management actions protecting native species, preventing the spread of non-natives and eradicating established non-native populations, even through a piecemeal process. The flexibility of an indicator reporting the percentage of species that are non-native is a key element of its design. Allowing this indicator to be broken out by taxonomic groups is critically important. The aggregate indicator will be biased towards the taxon with the most species, potentially masking important trends occurring within only one taxon. The high proportion of all vertebrates that are non-native, for example, is mostly due to the high proportion of introduced fishes and established non-native birds, the two most species-rich taxa. The within-taxa information can alert researchers or managers to groups that may deserve a higher or lower priority. Application of this indicator could be viewed analogously to an epidemiological examination of the prevalence of a disease in a population (e.g. Galen and Gambino 1975). In our case, the percentage of species that are non-native could be viewed as the percentage of a population (percentage of species in an ecosystem/geographical unit) that is infected (non-native).

Number of new non-native vertebrate species established over time

Reporting new introductions of non-native species that become established per unit time (e.g. per 5- or 10-year periods) emphasises the rate at which colonisation has been occurring. In addition to the spatial data requirements described above, this reporting strategy requires that each occurrence record for an established non-native species has a date of introduction (detection). A non-native species that becomes established in multiple geographic locations over time will be counted again for every new ecosystem or area that it colonises. However, the overall number of unique non-native species established for the first time within the entire area or ecosystem under consideration

should also be reported. With this design, the indicator at a national and also a local scale will respond to both the spread of non-native species already established and species never before established. Tracking the number of newly established non-native species estimates the rate of biological invasion through time. The likelihood of an introduction occurring with negative ecological, economic or health consequences increases with the number of new establishments. As with the percentage of species that are established, this indicator also can be aggregated across taxa and ecosystems to create another core national indicator. Application of this indicator also is analogous to the epidemiological descriptor, incidence or the rate of new disease cases in a population (e.g. Galen and Gambino 1975). That is, the number of new non-native species per unit time within an ecosystem/geographical unit would be analogous to the new cases of infection in a population per unit time.

Quantification of historical trends for non-native species' introductions may improve the ability to predict future introduction rates, since these trends reflect social and commercial activities that have created opportunities for species' introductions. Information on introductions could also help monitor positive feedback among species' introductions ('invasional meltdown', sensu Simberloff and Holle 1999). For example, case studies from the Great Lakes and elsewhere indicate that the presence of non-native species can increase the susceptibility of an ecosystem to invasion by additional species (Richardson *et al*. 2000; Ricciardi 2001; Floerl *et al*. 2004; Grosholz 2005). Similarly, the growth and expansion of the invasive brown tree snake's population on Guam was greatly exacerbated by the establishment and population growth of non-native lizard species, thereby providing key components to the snake's food base throughout its life cycle (e.g. Fritts and Rodda 1998).

The number of new non-native species can be used to assess the success of prevention efforts by providing a measure of accountability for national scale programs. The National Invasive Species Council has stated in its management plan that preventing the establishment of non-native species is 'the first line of defense and, over the long term, the most cost-effective strategy against invasive species' (NISC 2001). Whereas an indicator reporting the proportion of species that are established non-natives will indiscriminately respond to efforts focused on preventing introductions, eradicating established non-natives and restoring populations of native species, this indicator reporting establishment of non-native species per unit time will respond specifically to efforts aimed at preventing new arrivals from becoming established.

We note that this indicator is not intended to target the frequency of re-introductions or the number of individuals introduced for each non-native species, collectively called 'propagule pressure'. The size of each introduction and the number of times a non-native species is introduced are major factors determining the likelihood of establishment. High propagule pressure presents more opportunities for a non-native species to establish successfully. Alternatively, a single release of just one or a few individuals is less likely to result in that species becoming established. Information on propagule pressure is not currently available at large spatial scales, but it eventually may be collected through mechanisms such as the US Department of Agriculture's Port Information Network (NRC 2002). However, since propagule pressure is only one of several factors in invasion success (others include species' characteristics and ecosystem susceptibility), reporting the number of detected newly established non-native species more accurately reflects actual levels of biological invasion.

Alternative reporting strategies considered

Many options for vertebrate indicators were considered in the course of identifying the indicators described above. To more fully report on the indicator selection process, we describe alternatives that were ultimately rejected for vertebrates.

Number of non-native vertebrate species

This indicator would report the numbers of non-native species in the USA, or at more local scales. It also could be reported in the aggregate for all taxonomic groups and could be broken out by ecosystem type and by taxonomic group. However, the percentage of all species that are non-native provides a more informative indicator, because having the data necessary to report a percentage indicator would make it

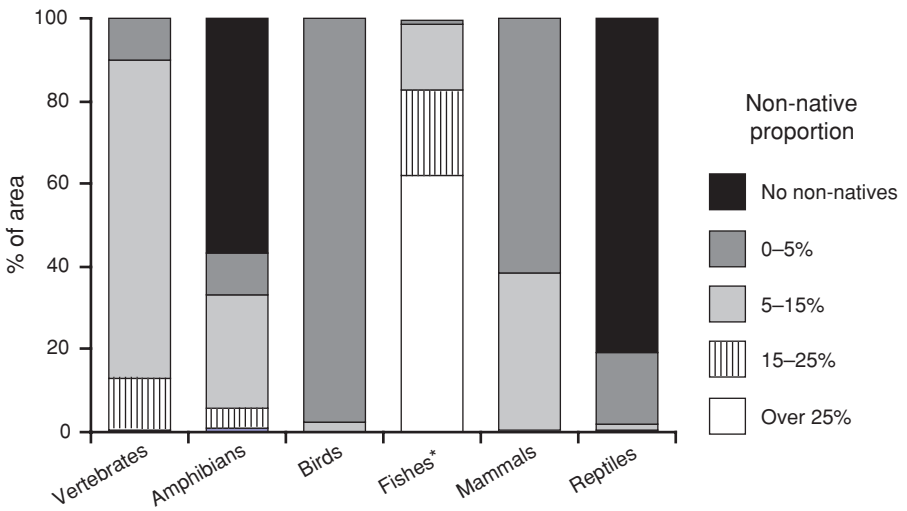

Fig. 1. An example of graphical application and taxonomic break-out for the percentage of vertebrate species in the USA that are non-native is shown on an area basis (all vertebrates combined are identified by the term 'vertebrates' on the *x*-axis). Native and non-native species lists were compiled for each watershed (determined by US Geological Survey 6-digit Hydrologic Unit Code) in the contiguous USA, and the percentage area was determined by the area of watersheds falling within each non-native percentage range. Data are from NatureServe and the USGS NAS database.

possible to have the number of non-native species established as a second-tier indicator.

Density of non-native vertebrates

This indicator would report the density of non-native vertebrate individuals in all ecosystem types. Although such information would be extremely valuable, collecting these kinds of information at any scale for all species is impractical owing to the extreme resources required for wide-scale application, and the inherent in-field and theoretical difficulties of validly estimating vertebrate population sizes (for example, see Liedloff 2000 for a discussion of the difficulties in obtaining valid mark-recapture estimates under even seemingly ideal circumstances).

Biomass of non-native vertebrates

An indicator that reports the biomass of non-native vertebrates was rejected primarily because of the range in organism size across vertebrates. The resulting index would be predominately controlled by species size and number, which would not necessarily reflect the degree of influence. For example, there is no general principle leading to an expectation that five northern snakehead fish will have any greater or lesser impact than one bighead or silver carp. Moreover, practical, but meaningful estimates of biomass of each species would likely not be possible to obtain.

Cropland impacts due to non-native vertebrate species

This indicator was originally designed to report changes in crop yields and the management costs resulting from invasive non-native species. This indicator was eliminated after discussions with the US Department of Agriculture, Agricultural Research Service. Negative effects on croplands are driven by many additional properties and processes, such as drought. Teasing out the effects of non-native species from confounding variables would require intensive research efforts.

Discussion

We have identified two indicators (percentage of species that are established non-natives and number of new non-native species established over time) that: (1) are informative and flexible enough to show relative changes in non-native species status over broad geographical scales, taxa and ecosystem types; (2) can be broadly applied without intensive data collection requirements; and (3) can be applied to aid assessment of management actions or policies at differing scales directed towards non-native species. Both indicators provide a perspective for assessing ecosystem health and health trends relative to non-native species and can be considered analogous to applications of descriptors of disease status in a population using prevalence and incidence statistics (e.g. Galen and Gambino 1975). The indicators also invite discussion concerning issues of data management, non-native species impacts and application.

Data management issues

Currently, the USA can say very little at the national scale about the overall trends and distribution of non-native species within its borders. Monitoring programs that consistently produce data that are scaleable, comparable and statistically defensible are critical to understanding the individual and cumulative effects of introduced species on managed and natural ecosystems and to examining the trends over time. Basic research and even conceptual frameworks on what to monitor and how to report the various kinds of data collected have needed development.

A key attractive feature of both indicators is the simplicity of the data they provide: species presence in a given area at a particular time. The data are potentially available from a variety of sources. However, completeness of data may vary among taxa and areas within the country, such as from state to state. Beyond whether accurate data exist to the scale necessary, the data may have to be accumulated from across multiple sources to calculate indicators at the appropriate scale.

As an example, consider calculating the percentage of vertebrates that are non-native from the watershed scale to the national scale. Other than the US Geological Survey (USGS), which collects data on non-native freshwater fish in USA watersheds, we know of no other federal agency with both native and non-native vertebrate data by species across the entire USA. However, that does not mean data for the other vertebrate taxa do not exist. Data are available from many sources, including state wildlife agencies and conservation organisations. For example, NatureServe, a nonprofit conservation organisation, has compiled much information, making it feasible to initiate indicator calculations, albeit with some minor data gaps (e.g. reptile information is incomplete for two states, and feral cats and feral dogs are not included). In terms of impacts on native species, dogs and cats are significant, especially for cats on birds, small mammals and reptiles. Nevertheless, it is safe to assume their constant ubiquity across landscape scales, and thus their omission, is unlikely to affect an indicator's ability to monitor trends in non-native species.

Non-native species impact assessment

The presence of an established non-native species is insufficient information to infer whether harmful impacts are occurring. A single population of a particular non-native species might have major effects on one system, whereas other systems could host many established non-native species without readily apparent changes in ecosystem characteristics. Therefore, it is important to stress that establishment of a non-native species does not equate with impact on an ecosystem, but having more established non-natives increases the chances that an invasive species is among the established non-natives. Our indicators provide information on the spatial and temporal trends of colonisation by non-native species, thereby providing probabilistic starting points for further investigation.

Most people care about non-native species because of their potential for negative effects on ecosystems, human health and economic assets. Hundreds of millions of federal and private dollars are spent annually on prevention and management of invasive non-native species because of the negative effects they can have in these areas. These impacts are in many cases not easily measured, however, and where measures of individual impacts are available they are often not comparable with other kinds of impacts. Assessing impacts would require national reporting to move well beyond cataloguing the presence of non-native species and documenting their locations. To build national information networks for non-native species impacts requires identification of the impacts in need of monitoring, the

scales and locations at which they should be monitored and the protocols, technologies, resources and infrastructure that would facilitate data collection.

Some of the difficulty in developing impact indicators stems from the complexity of ecological systems. For example, if a fish community's ability to resist an invasive non-native pest species was severely weakened by a prolonged drought, then infestation of the watershed by invasive non-native pests potentially could result in native species population declines, which could be documented. However, the difficulty in developing the indicator arises in attributing the cause of loss, as population reductions among native species could be due either to drought or to the pest, or their synergy.

Policy makers and natural resource managers would likely find direct impact indicators most useful in the decision making process, if they could be developed at the necessary scales. Attempts have been made to estimate on a national scale the economic impacts of non-native species (e.g. Pimentel *et al*. 2000). However, such estimates require a series of assumptions and extrapolations since explicit comprehensive datasets do not exist (Corn *et al*. 2002). At the same time, information on the distribution and spread of established non-native species, even those not known to cause harm, would greatly improve basic ecological understanding of how established non-native species can change the structure and function of ecosystems. Monitoring established non-native species is likely to be necessary to understand whether those changes are likely to be harmful, but with respect to known invasives, quantifying the degree of impact itself ultimately would be critical to documenting the condition of ecosystems invaded by non-natives. The indicators presented here provide probabilistic groundwork for where impacts would likely be found.

Application considerations

The two indicators, taken in combination, will provide policy makers and managers a general overview from which to guide decisions and funding priorities for actions to be taken. On large scales (national, entire state), the indicators will provide current condition and trends in ecosystems' health relative to non-native species. As already seen, the two indicators of ecosystem health relative to non-native species are descriptively analogous to the use of prevalence and incidence to describe a disease situation (e.g. Galen and Gambino 1975). The two indicators, the percentage of species that are non-native and the number of new non-native species established over time, examine ecosystem health from different perspectives. It is possible for one to be high while the other is low. For example, the percentage of species that are non-native can be quite high, but the number of new non-native species could be low. This would be good news for Florida where there are a great many non-native species established (e.g. US Congress 1993, Corn *et al*. 2002), but a slowing of new establishments would indicate that policy or legislative directives for the pet industry and exotic species' ownership have been successful at stemming the tide of new introductions. In contrast, the percentage of species that are non-native can be low, but the number of new non-native species could be high. This could indicate a call to action for measures to curtail the flow or initiate eradication efforts before non-native species have an overwhelming influence in a relatively pristine ecosystem.

Consider again the example of calculating the percentage of vertebrates that are non-native. Even though there are some data gaps, the indicator calculations provide insight into the health of individual watersheds across the nation. Using data available from the aforementioned NatureServe and the US Geological Survey (USGS), the Heinz Center has been able to demonstrate the feasibility of calculating this indicator from existing data sources and provide a picture of the situation for non-native vertebrates in the USA (see Fig. 1). Approximately 15% of the watersheds have between 0 and 5% non-native species. The largest percentage of watersheds (~52%) have between 5% and 10% non-native vertebrate species (Heinz Center, unpubl. data). Getting back to the Florida example, the south Florida/everglades watershed has the worst situation, with over 25% non-native species. Although this statistic is rightly viewed with alarm, many factors should be taken into consideration before initiating management actions. Consequently, when it is also considered that much of the native habitats of south Florida have been lost to development and there are many threatened and endangered species in the region (e.g. Corn *et al*. 2002), then non-native species are more likely to have severe impacts on native species (e.g. Hecht and Nickerson 1999; Salo *et al*. 2007), and an emphasis should be placed on policy and management directions to mitigate the non-native species issue there (e.g. US Congress 1993; Corn *et al*. 2002).

Final comments

Little has been published on policy or practice for quantitative indicators to monitor non-native species on a national scale, especially for geographically expansive nations. Besides our effort, Australia also is pursuing the concept of monitoring invasive species on a national scale, with the flexibility to address smaller scales as well (Gibson and West 2006). Although they are focused on invasive species more so than non-native species, many of the criteria for data collection and management and consistency and flexibility in reporting are similar to the needs identified for the USA. We have introduced here indicators for non-native vertebrate species identified as part of 'The State of the Nation's Ecosystems' project by the Heinz Center. The indicators require a minimum of data and offer reporting consistency across ecosystems and geographic scale. These indicators reveal important characteristics of ecosystem conditions, are readily interpreted by non-technical readers and can inform policy makers. Information is needed at the scale (national, state, local) of potential and implemented funding initiatives to evaluate the need for action and to evaluate outcomes. In a probabilistic sense, they also inform about the potential for negative impacts (more non-natives imply a greater probability for negative impacts). These indicators maximise flexibility across spatial scales, taxonomic groups and ecosystem types and, for the most part, data are available (but not generally accumulated nationally) to calculate the indicators.

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